Uncovering the Most Vulnerable in Times of Crisis: Analyzing Procurement Capacity Index with Multi-Criteria Decision-Analysis

John Raymond B. Barajas

Abstract— **This paper presents a multi-criterion decision analysis approach to developing a procurement capacity index for local government units (LGUs) in the Philippines. The index serves to assess the resilience of LGUs in times of crisis, particularly in the context of the COVID-19 pandemic. This study utilized two open datasets published by the Philippine government from January to June 2020, and identified five criteria for the procurement capacity index: total approved budget of the contract, internal revenue allotment, number of awarded tenders, number of tenders posted, and fund utilization rate. This study then employed the criterion impact loss (CILOS) method to determine the weight vectors of the identified set of criteria, and calculate the index as a weighted sum based on these vectors. This study found that the fund utilization rate and internal revenue allotment are the two most important criteria for determining the capacity of an LGU to secure goods or services during a crisis such as the pandemic. This insight is consistent with observations drawn from use cases in the US, UK, and Canada as revealed in reviewed literature. Results also revealed that LGUs can be categorized into three clusters based on their procurement capacities: low, medium, and high. Moreover, the developed index facilitated the ranking of LGUs according to their procurement capacity, revealing that LGUs located in Regions II, III, VI, VII, VIII, and X have insufficient budget allocation, thus strongly suggesting urgent intervention from the national government. Overall, the developed index can serve as a valuable decision aid tool to assist the government in identifying LGUs that need additional support to procure resources or services required to mitigate the consequences of a crisis.**

I. Introduction

The Philippines, like many other countries in Southeast Asia, has been severely impacted by the global COVID-19 pandemic. The first confirmed case in the country was reported on January 30, 2020 [1], and since then, a continuous rise in positive cases has been confirmed during the first quarter of 2020. In addition, the fifth reported case was identified as the first local transmission in the country, indicating the virus had started spreading within the community [1]-[2]. As of April 4, 2023, the Philippines has confirmed a total of 3.6 million COVID-19 cases, with 49 thousand active cases, 3.5 million reported recoveries, and 57 thousand COVID-19 related deaths [3].

To curb the spread of the virus, the Philippines implemented a series of lockdowns and control measures starting on March 17, 2020, in the regions of Luzon, Visayas, and Mindanao [4]. Areas with a continuous rise in confirmed cases were placed under Enhanced Community Quarantine (ECQ), the strictest level of lockdown, which imposed stringent measures to limit the movement and transportation of people between regions [5].

While mobility restrictions have been lifted due to controlled positivity rates in the country, there are still significant spikes in COVID-19 cases, particularly during holiday seasons [3]. If this trend continues, the healthcare system in the country may become overwhelmed once again, as evidenced from various hospitals reporting 100% occupancy rates at the height of the pandemic [6]. This is a concerning development, indicating that COVID-19 can spread rapidly in the country without adequate mitigation measures. It is then imperative to take urgent steps to mitigate the virus's spread and prevent the healthcare system from being overwhelmed again.

An effective procurement system characterized by prompt response, good cost-efficiency management, flexibility to adopt in unpredictable situations, and supply chain and system reliability is therefore critical to the success of humanitarian relief operations especially in times of disaster or health emergencies [7]. In the case of the Philippines, the government has taken steps to address the challenges posed by the pandemic by passing the Bayanihan to Heal as One Act (Republic Act 11469). This act allows for a more flexible and relaxed government procurement system, including the prioritization of critical goods and services necessary to control the spread of COVID-19 in the country [8]. For instance, Under *Section 4 – Authorized Powers: k*, the law grants the government the authority to expedite and prioritize the procurement of critical goods and services necessary to control the spread of COVID-19 in the country [8]. These include but are not limited to:

- goods necessary for health facilities and private laboratories with the capacity to test for suspected COVID-19 patients;
- goods and services for social amelioration measures;
- the establishment, construction, and operation of temporary medical facilities;

Parallel to this development, the Government Procurement Policy Board (GPPB) has also issued new resolutions to supplement the newly enacted law [9]-[12]. These resolutions amended the Government Procurement Reform Act (Republic Act 9184), allowing for the acceleration of procurements related to mitigating the consequences of

J. R. Barajas is with the Bicol University College of Engineering Chemical Engineering Department, Legazpi City, Albay, Philippines (email: jrbbarajas@bicol-u.edu.ph)

national emergencies and disasters. By streamlining these procurement processes and prioritizing the acquisition of essential items such as personal protective equipment, medical supplies, and testing kits, it is expected that local government units (LGU) in the country could be equipped with the resources needed to mitigate the impact of the pandemic on the healthcare system and society at large.

While the recent amendments to the procurement process are crucial to support the government's COVID-19 response and mitigate the pandemic's socioeconomic impact on Filipinos, there are concerns over the unequal distribution of government funds. Exploration of bid and award notices data from the Philippine Government Electronic Procurement System (PhilGEPS) for January to June 2020 suggests that government resources were largely allocated to major cities such as Metro Manila, leaving less developed cities and municipalities with limited resources [13]. This inequality is further evident in the disparity in COVID-19 testing, with 75.5% of the tests conducted solely in the National Capital Region (NCR) [14]. This unequal distribution of resources is therefore a serious issue and requires immediate attention to ensure that all Filipinos, regardless of their location, have access to the necessary resources to fight the pandemic.

In an attempt to address the identified issue, this paper proposes an indexing system that combines unique attributes of each LGU into a single criterion to describe their procurement capacity. Using a multi-criteria decision analysis approach, factors such as the total approved budget of the contract, internal revenue allotment, number of awarded tenders, fund utilization rate, and number of posted tenders are considered to identify LGUs with the lowest procurement capacity. The primary aim therefore of this work is to streamline the distribution of funds throughout the country, with the index serving as a tool to pinpoint LGUs that may be most vulnerable during times of disaster or health emergencies due to their capacity to procure resources and services. By doing so, this indexing system is seen to have the potential to improve the efficiency and effectiveness of fund allocation across the nation.

II. Methodology

This paper employed a multi-criterion decision analysis (MCDA) approach to create the procurement index based on the following criteria: (a) total approved budget of the contract, (b) internal revenue allotment, (c) number of awarded tenders, (d) number of tenders posted, and (e) fund utilization rate (see Figure 1). To achieve this objective, the criterion impact loss (CILOS) method was adopted as seen [15]. The CILOS approach was used instead of other MCDA methodologies since this has been proven to accurately calculate weight vectors of a set of criteria which could be correlated to each other [15]-[16].

A. Source of Data

This study utilized data from two open datasets provided by the Philippine government. The first dataset consisted of bid and award notices, including tenders tagged under the Alternative Mode of Procurement, published from January to June 2020 [13]. It contained 40 features describing the contents of a government tender and totaled 1 GB in size. To ensure comprehensive coverage, tenders outside the Philippine Government Electronic Procurement System (PhilGEPS) were also included in this study, with additional data sourced from the GPPB Online Portal for COVID-19 bids [17].

The second dataset utilized in this study contained internal revenue allotment (IRA) data for each LGU in the Philippines [18]. It contained 11 features summarizing the IRA of LGUs in the Philippines from 2009 to 2018. As 2020 IRA data was not available, IRA for each LGU was projected to increase by a factor of 1.125 annually in accordance with the memorandum issued on May 15, 2019, which informed a 12.5% increase in the IRA of all LGUs in the country [19].

Figure 1. Overview of employed methodology.

B. Data Cleaning and Processing

The two datasets utilized in this study were provided in a CSV format in long form, requiring minimal cleaning prior to analysis. However, the main challenge encountered in data preparation was merging the PhilGEPS data with the IRA data due to differences in their respective formats. For instance, the PhilGEPS data used a reference ID for LGUs, while the IRA data listed LGU names across multiple columns. To facilitate accurate merging, the Philippine Standard Geographic Code (PSGC) was introduced as an additional feature in both datasets, enabling a consistent index to be established [20].

C. Selection of Criteria

The criteria used in this work was primarily based on the definition of a COVID-19 resilient procurement system, of which defines an ideal LGU as one that can maximize its authority to procure resources or services needed to mitigate the impact of COVID-19 to its constituents [21]. For instance, an LGU demonstrates a resilient procurement system if it is able to do the following:

- implement effective surveillance systems for contact tracing;
- continuously adapt financial measures for COVID-19 treatment costs;

- implement concrete plans to maintain routine healthcare services alongside COVID-19 patients;
- essential medicines and critical care treatment for COVID-19 patients are made readily available;
- ensure regular training for health personnel to adhere to infection prevention and control protocols;
- provide quarantine and other related facilities that separately houses suspected and infected individuals

With these identified key characteristics, an LGU will therefore able to sustain critical tasks and effectively mitigate the socio-economic impacts of the COVID-19 pandemic on their constituents based on the following five (5) features in the collated dataset:

- *Total Approved Budget of the Contract (ABC, C1)*: this criterion refers to the approved budget for the contract (ABC) that a government procurement entity, such as an LGU, allocated for the acquisition of a specific good or service through the tendering process.
- *Internal Revenue Allotment (IRA, C2)*: this criterion pertains to the annual budget allocated by the Philippine national government to an LGU.
- *Number of Awarded Tenders (C3)*: this criterion refers to the total number of tenders awarded to a bidder by an LGU.
- *Number of Tenders Posted (C4)*: this criterion refers to the total number of tenders posted by an LGU in the PhilGEPS online portal.
- *Fund Utilization Rate (C5)*: this criterion refers to the proportion of the total ABC (Approved Budget for the Contract) for all tenders, including those awarded, failed, short-listed, and active tenders, posted by an LGU, against the sum of ABCs for all awarded tenders.

D. Criterion Impact Loss Methodology

The procurement capacity index was developed using the CILOS method to determine the objective weights of the identified criteria, as detailed in previous studies [15]-[16]. The dataset was structured into a 1030-row by 5-column matrix, with no minimization required. After normalization and identification of the highest values in each column, a relative loss matrix and a homogeneous system were used to calculate the weight vectors for each criterion. The weight vector values were obtained by normalizing the solution to the matrix containing the identified criteria variables (e,g, fund utilization rate).

E. Procurement Capacity Formula

Once the weight vector values for each identified criteria were calculated, the procurement capacity of each LGU were then determined from the weighted sum of the collated data as in (1).

$$PC = w_1C_1 + w_2C_2 + w_3C_3 + w_4C_4 + w_5C_5 \quad (1)$$

where PC represents the procurement capacity of an LGU, C_1 to C_5 are the identified criteria: total approved budget of the contract (million Php), internal revenue allotment (million Php), number of awarded tenders, number of tenders posted, and fund utilization rate (%), w_1 to w_5 are the values of the weight vectors relative to each identified criteria. Ranking of the most vulnerable LGUs was then based on the calculated procurement capacities.

III. Results and Discussion

A. Descriptive Summary of the Collated Data

Table I summarizes the descriptive statistics of the data containing the five identified criterion labeled C_1 through C_5. As shown, these statistics provide valuable information about the distribution of the dataset and the range of values observed for each variable. For instance, it could be inferred that the standard deviations for each criterion are greater than the arithmetic mean calculated. This observation strongly indicates that a wide range of variability in the calculated LGU procurement capacities should be expected. Moreover, the minimum value of 0 for both C_3 and C_5 indicate there are LGUs which were not able to award a tender between January to June 2020. This result is shown to be a precursor to the fact there are indeed LGUs who were not able to procure resources or services at the height of the pandemic.

TABLE I. Descriptive Statistics of Dataset

Statistic	C_1	C_2	C_3	C_4	C_5
mean	178.9	222.1	8.6	133.8	23.2
standard deviation	786.3	336.6	13.0	182.5	26.0
min	1.7	36.0	0.0	1.0	0.0
max	16147.6	4844.4	145.0	2650.0	100.0

B. Criterion Weights

Table II presents the calculated weights for each criterion identified. The findings reveal that the fund utilization rate emerges as the most significant criterion when evaluating the procurement capacity of a Local Government Unit (LGU) during disasters or health crises. Following closely is the Internal Revenue Allotment (IRA), which represents the annual budget allocated to LGUs by the Philippine national government. While these results may be context-specific to the Philippines, the existing literature strongly supports the notion that efficient acquisition of resources and services in a timely and effective manner is a critical factor in assessing public procurement effectiveness universally [22]-[26]. For instance, studies conducted in the US, UK, and Canada have shown that efficient utilization of government funds is crucial in ensuring that the health sector receives the necessary resources and support to effectively respond to crises such as the COVID-19 pandemic [22]. Conversely, failure to utilize funds efficiently and promptly may result in wastage of resources and hinder efforts to mitigate the consequences of a crisis [22]-[26]. Overall, the alignment of the results of this study with the findings of the reviewed literature strongly

supports the validity of the calculated weights for the identified criteria.

C. Clusters of Local Government Units

To make the calculated procurement capacities more meaningful, agglomerative hierarchical clustering with Ward's method was implemented [27]-[28]. Initially, a delta between 1500 and 2000 was set to form two LGU clusters (outliers that fell outside 1.5 times the interquartile range in both positive and negative directions were removed to better identify meaningful and more homogenous clusters). However, it was observed that the second cluster formed had larger ranges for each identified criterion (e.g., C_1 ranging between 8 to 240 million Php). To address this issue, the second cluster was further divided into two groups using a delta of 1300, resulting in a total of three clusters. The resulting clusters are visualized in Figure 2 and Figure 3.

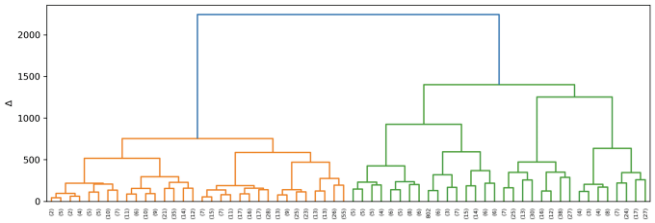

Figure 2. Results of Implemented Ward's Method.

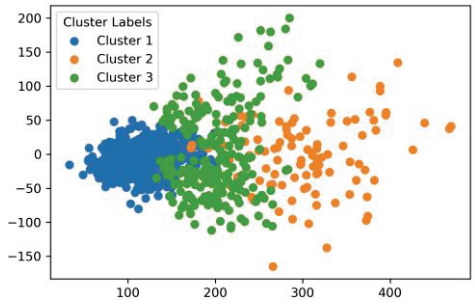

Figure 3. 2D Visualization of Formed Clusters.

TABLE II. CALCULATED CRITERION WEIGHTS

Criterion	Criterion Weight
C_1	0.16
C_2	0.22
C_3	0.17
C_4	0.19
C_5	0.26

TABLE III. DESCRIPTIVE STATISTICS OF CLUSTERS FORMED

Statistic	C_1	C_2	C_3	C_4	C_5	PC
Low						
mean	36.5	93.1	4.5	49.0	22.5	39.2
standard deviation	23.4	25.1	5.7	24.9	26.3	13.1
min	1.7	36.0	0.0	1.0	0.0	8.0
max	132.6	163.1	30.0	116.0	98.9	81.1
Medium						
mean	54.0	150.5	6.4	104.0	20.1	63.4
standard deviation	26.0	41.5	7.9	59.9	23.9	15.7
min	8.5	59.4	0.0	11.0	0.0	36.4
max	184.2	268.3	29.0	298.0	90.0	110.2
High						
mean	138.7	217.6	8.0	129.5	24.5	95.6
standard deviation	53.9	62.8	7.6	59.6	26.6	19.8
min	28.0	53.6	0.0	10.0	0.0	55.7
max	237.9	344.2	28.0	281.0	96.2	150.7

D. Interpretation of Formed Clusters

Table III summarizes the descriptive statistics of the formed clusters. Based on these results, the formed clusters could be interpreted as follows:

- *LGU with Low Procurement Capacity (Cluster 1, 453 LGUs)*: this cluster represents LGUs with low procurement capacity index, averaging to 39.2. These are LGUs with an estimated average annual allocated budget amounting to 93.1 million Php.
- *LGU with Medium Procurement Capacity (Cluster 3, 262 LGUs)*: this cluster represents LGUs with medium procurement capacity index, averaging to 63.4. These are LGUs with an estimated average annual allocated budget amounting to 150.5 million Php.
- *LGU with High Procurement Capacity (Cluster 2, 102 LGUs)*: this cluster represents LGUs with high procurement capacity index, averaging to 95.6. These are LGUs with an estimated average annual allocated budget amounting to 217.6 million Php.

In addition, it can be inferred that: (1) LGUs with procurement capacity index below 63.4 can be categorized as LGUs with low procurement capacity or those that would require immediate attention from the national government; (2) LGUs with procurement capacity index between 63.4 and 95.6 can be classified as LGUs with medium procurement capacity; and (3) LGUs with procurement capacity index greater than 95.6 can be classified as LGUs with high procurement capacity. These generalizations therefore could provide a useful framework for decision-making and resource allocation especially in times of disasters or health-emergencies.

E. Practical Implications of Findings

The present work offers two significant contributions: (1) identification of vulnerable LGUs, and (2) potential integration of the developed procurement capacity index in the PhilGEPS online portal.

Regarding the first contribution, the developed procurement capacity index serves as a single quantifying variable that can easily identify LGUs that are most vulnerable during health emergencies or disasters such as the COVID-19 pandemic. For instance, the LGUs of Uyugan, Batanes, and Balingoan, Misamis Oriental were immediately identified as having the least capacity to procure resources or services needed in times of crisis (as summarized in Table IV). These two LGUs posted a combined number of 11 tenders from January to June 2020 totaling to 4 million Php, which is significantly lower compared to the average total approved budget of the contract of 36.5 million Php for LGUs with low procurement capacity. According to the 2020 Philippine census [29], this allocation would only translate to Php333.33 per capita, falling short by at least Php2700.00 compared to the average of an LGU with low procurement capacity for a population of 12,000. To put this amount into context based on the published prices of COVID-19 vaccines [30], this allocation per capita would only cover the complete COVID-19 vaccination of an individual but not any critical care expenses if such an individual contracts COVID-19. These inferences therefore provide a concrete example on how the developed procurement index would be useful in identifying LGUs with the least capacity to procure resources or services during a crisis.

TABLE IV. RANKING OF LOCAL GOVERNMENT UNITS

LGU Name	Province	Region	PC	Rank
Uyugan	Batanes	II	8.0	1st
Balingoan	Misamis Oriental	X	11.0	2nd
Sikatuna	Bohol	VII	14.8	3rd
Pagsanghan	Western Samar	VIII	14.9	4th
Anahawan	Southern Leyte	VIII	15.2	5th
Rosario	Nothern Samar	VIII	15.3	6th
San Enrique	Negros Occidental	VI	15.9	7th
San Rafael	Iloilo	VI	16.2	8th
Nampicuan	Nueva Ecija	III	16.3	9th
Kinoguitan	Misamis Oriental	X	16.4	10th

As the final contribution of this work, the developed procurement index has the potential to be a valuable decision aid tool for the Philippine government in planning and monitoring budget allocation, particularly for those deemed most vulnerable in times of crisis. One way this can be achieved is by integrating the procurement capacity index into the PhilGEPS website and displaying it as a dashboard (see Figure 4). This would then allow the Philippine government to identify LGUs that need to be prioritized in the present fiscal year and simultaneously track the procurement capacities and progress of these LGUs over time. For instance, LGUs, such as Uyugan, Batanes and Balingoan, Misamis Oriental, have been identified through the developed procurement capacity index to have limited budget allocation and this limits the number of tenders they can post. This weakness revealed by procurement capacity index could then be used to lobby immediate support from the national government and justify approval for the request of additional budget in the Philippine congress. Overall, just by knowing the procurement capacity index of an LGU, the Philippine government can easily identify regions where they need to focus their efforts on to achieve equitable distribution of funds across all LGUs in the country.

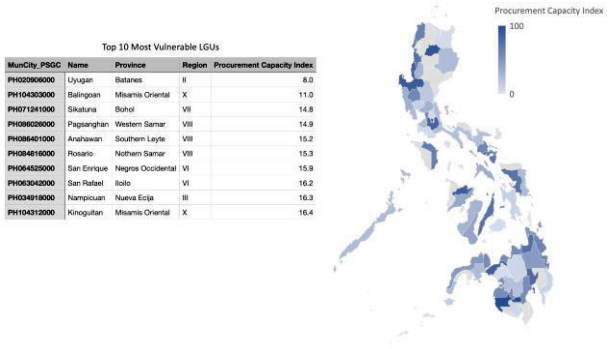

Figure 4. Sample Dashboard Featuring the Procurement Capacity Index.

IV. FUTURE WORK

This study recognizes that the procurement capacity index may not be fully comprehensive, as there are other important criteria, such as the number of COVID-19 cases, number of hospitals, hospital bed capacity, calamity fund allocation and utilization rates, and the number of bidders available, which should also be taken into consideration [21]-[26]. Although efforts were made to gather data related to these criteria during the dataset collection phase, the lack of data posed a significant challenge to their inclusion. For example, COVID-19-related data in rural areas of the Philippines, particularly those in remote locations, were not readily accessible due to limited budget allocations for testing from January to June 2020, as observed in the findings of this study. Nevertheless, in future iterations of this study, it is therefore recommended to include these additional criteria once data is more accessible. This will ensure a more comprehensive evaluation of the procurement capacity of LGUs, which is projected to help improve their planning and monitoring of budget allocation, particularly during times of crisis.

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